DESIGN OF ELECTRIC LOCOMOTIVE FOR C. B. & Q. R. R.

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Design of Electric Locomotive for C.B.& Q.R.R.

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CONTENTS

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(1) Introduction

The lines of Chicago,Burlington,and Quincy Railroad extend from Chicago to many industrial and agricultural states of the west, and also are in connection with the Great Northern system,the one the great trans-continental railroad in this country.

The traffic in the section between Chicago and Aurora, is heavy as the trains from all parts of the system are converged into this section, and also the regular suburban service is maintained.

An electrification of this section of the railroad has been proposed by Messrs.F.G.Hazen and W.G.Martin of the class of 1912,Armour Institute of Technology,as their thesis.

The electric locomotive,I designed, is to haul the through passenger train in the section above mentioned, a distance of thirty seven miles.

(2) Character of profile.

The character of this section of railroad is best shown by the track profile which was kindly rent by my freind named above.

From Chicago westbound the line is practically level for about four miles; for the next sixteen miles to Greggs, the ruling grade is 0.816 percent. From Greggs to Lisle, a distance of five and a half miles, is an average down grade of 0.375 percent. From Lisle to Naperville, a distance of four miles, is a ruling grade of 0.55 percent. From Eola to Aurora,we have an average down grade 0.27 percent.

As there are practically no heavy grades and sharp curves,the condition is in best advantage for the high speed operation.

At the present, the steam locomotive of heavy pacific type is used, it covers this section in fifty-five minutes, with heavy passenger train, corresponding to the schedule speed of about fifty miles per hour.

(3) Design of the locomotive.

The train, which is to be hauled by the electric locomotive, was assumed to consist of ten cars of following descriptions and weight:

1 Baggage car	70 tons
1 Dinning car	40 tons
3 Tourist sleeping cars	120tons
1 Buffet car	70 tons
3 Standard sleeping cars	180tons
1 Mail car	40tons
Total ten cars	520 tons
Electric locomotive	115tons
Total weight	635 tons

The schedule speed for the electric locomotive is fifty miles per hour. But City of Chicago restricts the speed to twenty miles per hour, within the city limit, so that Western Avenue station, a distance of four miles, is reached in twelve minutes. For the rest of trip, the maximum speed of fifty- nine miles per hour must be maintained. Acceleration was assumed to be 0.8 mile per hour per second, which is a fair value for the through train.

The tractive effort required to accelerate the above train on a 0.816 percent grade, using a friction of ten pounds per ton, seventy two and eight tenth pound per ton for acceleration, is 52,500 pounds. This gives the coefficient of friction of 22.8 percent.

(4)Description of the locomotive:

The locomotive is of Prairie type (o-000-o),the type commonly used in fast passenger locomotive. It has a total weight of 230,000 pounds of which 150,000 pounds is on three pairs of driver, 80,000 pound is carried by two pairs of radial axle wheel.

Each of the two inter-pole motors is connected to a jack-shaft by means of a pairsof connecting rod placed on either side of the motor and making an angle of ninty degrees. The jack-shaft is connected to the drivers by means of side-rods,and it is also connected to the other jack-shaft. All rods and moving parts have pure rotation, and are counterbalanced.

(A) Wheels:

The total wheel base is 29 feet 6", while the rigid wheel base is 15 feet 6". The gauge is 4feet 8 1/2". The drivers are 75" in diameter,and is made of cast steel. The leading and trailing wheels are 36" in diameter, and is made of the same material as that of driver. These wheels are provided with Webb's radial axle-box which allows them a maximum of about 1 1/2" side play on each side when the locomotive is on a curve. This axle-box consists of curved guides rivetted to the frame of the locomotive,and a spring frame is fixed to the center of the guides. The radial axle-box is made of cast iron,and extends across,between and through the frames,being curved to slide transversely in the guides. Bearing of ordinary description are fitted at either end of the radial axle-box. Attached to the spring is a rod which pass through the spring frame and is connected to the horizontal spring.

When the locomotive enters a curve, the spring compressed toward (4) one side, allowing the box to slide laterally in the guides. All drivers are supported on semi-elliptical springs,which are hang beneath the journal box saddles. The shaft for the driver is 8" in diameter at the bearing and 7" at the middle. Material is of steel. The shaft for the other wheel is 5" in diameter at the bearing, and 4" at the middle. The jack-shaft has uniform diameter of 8", which will withstand the twisting moment of 2,250,000 inch-pounds. All crank pins are made of steel,and is case-hardened.

(B) Frames:

The frames are steel castings , and are made heavier than actually required in steam locomotive. Owing to the fact that forces acting on the frames were complicated,I could not determined the dimensions,but various,practical examples of heavy steam locomotives, have been applied. The coupling is of standard M.C.B. The braking equipment consists of two12" x 10" air brake, one is placed on the center line of the locomotive and near the front end; the other, on the same line but near the back end. Both brakes can be simultaneously operated from the engineer's room.

(C) Cab:

The cab is 32 feet 11 inches long, 10 feet wide, and is 13 feet 7 inches high above rail head. It is carried on I-beams,and is rivetted to the frame. The cab is made of steel plate 1/8" thick and the inside is finished with wood. There are twenty windows of which one on each side is provided with door and serves as an entrance, and hand rails are provided. There are two engineer's operating rooms,one on each end and is separated by steel-plate wall extending from floor to the roof. The room is 4 feet 6" x 3 feet 5".

The Equipment in the room is as follows:
1 master controller, 1 air brake controller, 1 emergency,hand operated brake, 1 push-button sander, 2 pressure gauges, 1 circuit breaker, 1 controller for pantograph , 1cut-out switch, electric heaters. The bell and whistle can be operated fromthis room. Opposite to the engineer's room, is anroom for all contactors, rheostats,and other auxilially apperatus for the main motor.

(D) Air compressors:

There are two air compressors of G.E.CP-30 type,driven by a series motor,which supply air for both air-brakes,and pantographs. The capacity is 35 cubic feet per minute . There are four air reservoirs, 48" x 16",under the cab, and outside of the frame. Working pressure is 90 pound per square inch.

(E) Power supply:

Power is supplied from the third-rail,at the voltage of approximately 600 volts. There are two pairs of double contact shoe,placed 4 feet 1" from the center of the track.Each pair is located at either side of the trailing wheels. The shoes are attached to a wooden block, bolted to an extended arm which is in turn rivetted to the frames. For use in switching in the yard where the trolley line is provided instead of the third-rail,a pair of pantograph is installed on the roof. It is operated by compressed air, the controller of which is in the engineer's room, at both endsof the locomotive.

(F) Motors:

There are two motors of inter-pole type, each one is placed 12feet 3 1/2" from the ends of the locomotive,and 7feet 3" from the rail head. The outside diameter is 76 7/8", the armature diameter is 60".

There are ten main and ten commutating poles. The brushes are attached to the extension of the yoke. Each motor is designed to develope 1280 H.P. at the speed of 10 miles per hour, corresponding to the tractive effort of 48,000 pound at the rim of the drivers. The maximum tractive effort is 60,000pound.

(5) Summary :

Total weight	230,000 pound
Weight on drivers	150,000 pound
Weight on other wheels	80,000 pound
Number of driver axles	3
Number of other axles	2
Diameter of drivers	75"
Diameter of other wheels	36"
Number of motors	2
Out-put of motor	1280 H.P.
Number of main poles	10
Number of commutating poles	10
Voltage	600 volts
Maximum speed	60 miles per hour
Maximum tractive effort	60,000 pound
Length of locomotive	37 feet 7"
Rigid wheel base	15feet 6"

(G) Control of motor:

The control is of Sprague-G.E. Type"M" multiple unit system. Controllers are arranged so that there will be nine steps in the series,and five in the parallel position. All auxiliary switches, contactors, and rheostats are situated in the switch room,while the master controller and cut-out switches are in the engineer's room.

Calculation of 1280 H.P. Inter- pole Series Motor.

Motor capacity = 1280 H.P. at 10 miles per hour.

Electrical out-put, corresponding to above rated H.P. = 960 K.W.

Electrical in-put, assuming an effciency of 90 % = 1070 K.W.

Voltage = 600 volts.

Revolutions per minute, at rated H.P. = 45.

Current in-put = 1780 amperes.

Efficiency = 90 %.

Number of poles = 10. (main pole).

Frequency = 5x 45 / = 3.75 cycles at 10 miles per hour.

= 5 x 270 / 60 = 22.5 cycles per second,at 60 miles per hour.

Armature.

Diameter over all = 60".

Circumference over all = 188".

Peripheral speed = 188 x 45 / 12 = 705 feet per minute, at 10 miles per hour.

= 188 x 270 / 12 = 4240 feet per minute, at 60 miles per hour.

Pole pitch at armature face = 188 / 10 = 18.8".

Length between flange = 24".

Steinmetz coefficient = 60 x 24 / 1070 = 1.35.

Number of ventilating ducts = 8 (3/8").

Percentage ventilation = $\frac{3/8 \times 8 \times 100}{24} = 12.5$ %.

Percentage insulation = 10 %.

Net length of core = 24 - (2.4 + 8 x 3 /8) = 18.6".

Percentage net length of core = 18.6 x 100 / 24 = 77.5 %.

Number of circuits = 10.

Amperes per circuit = 178.

Style of winding, simplex, singly reentrant, lap winding.

Number of conductors = 580. (4 conductors in each slot).

Pitch of winding = 58.

Number of slots = 145.

Dimension of conductor in bare = 178 / 1500 = 0.119 square inches.

Conductor 0.2" x 0.6".

Insulated coductor 0.24" x 0.64".

Width of slot = 0.66". (at top).

Depth of slot = 2.36".

Ratio of depth and width = 2.36 / 0.66 = 3.6.

Space factor = 4 x 0.1 / 2.36 x 0.66 = 0.257.

Width of tooth at top = (188 - 145x 0.66)/ 145 = 92.4/ 145 = 0.635".

Width of tooth at bottom = 0.54".

Average width of tooth = 0.5875".

Depth of core below slot = 5".

Internal diameter of core = 60 - (2 x 5 + 2 x 2.36) = 45.28".

Thickness of lamination = 0.02".

Mean turns of wire = 2 x 18.6 - 2.5 x 18.8 = 86.2".

Total number of armature turns = 580 / 2 = 290.

Turns between - and + brushes = 290 / 10 = 29.

Length between - and + brushes = 29 x 86.2 / 10 = 250".

Total number of parallel path = 10.

Resistance of wire at 60°C = 9.5 x 250 / 12x 100,000 = 0.00198 ohms.

IR drop at rated H.P. = 0.00198 x 1780 = 3.52 volts.

Number of armature ampere turns per pole = 29 x 178 = 5150.

Ampere conductor per inch of periphery = 580 x 178 / 188 = 550.

Field core. (main field).

Depth of air gap = 3 / 16".

Diameter of pole piece bore = 60 + 2 x 0.188 = 60.376".

Percentage polar embrace = 70 %.

Average length of polar arc = 60.376 x 3.14 x 0.7 / 10 = 13.3".

Width of pole face = 24".

Area of pole face = 24" x 13.3" = 320 square inch.

Thickness of pole shoe = 3/4".

Axial length of field core = 24".

Width of pole core = 11.3".

Area of cross section = 24" x 11.3" = 271 square inch.

Radial depth of core = 4".

Yoke.
Internal diameter = 60.376 + 2x 0.75 + 8 = 69.876".

Width of yoke = 32".

Thickness of yoke = 3.5".

Sectional area = 32" x 3.5" = 112 square inch.

External diameter = 69.876"+ 7" = 76.876".

Mean diameter = 73.376".

Commutator.

Turns per segment = 1.

Number of segment = 580/2 = 290.

Volts per segment = 600/ (290/ 10) = 20.7 volts.

Thickness of segment = 0.5".

Thickness of insulation = 0.02".

Diameter of commutator = 0.52 x 290 / 3.14 = 48".

Peripheral speed = 48 x 3.14 x 45 / 12 = 565 feet per minute, at 10miles per hour.

= 3380 feet per minute, at 60 miles per hour.

Useful length of commutator = 1780/(5x 50) = 7.15 square inch.

Assume 50 amperes per square inch.

Length of commutator = 4 x 1.5 - 2 x 0.5 = 7".

4 brushes of 1.25" x 1.5".

Cross section of commutator riser 0.2 square inch.

Length of commutator riser = (60 - 48) / 2 = 6".

Useful depth of commutator = 1.25".

Total depth of commutator = 3".

Area of commutator surface = 3.14 x 48 x 7 = 1050 square inch.

Brushes.

Number of sets = 10.

Current per brush = 1780 / 5 = 357 amperes.

Material, carbon.

Contact surface per set = 7.15 square inch.

Thickness of brush = 1.25".

Length of brush = 1.5".

Area of each brush = 1.88 square inch.

Number of brush per set = 4.

Maximum number of segment covered = 3.

Contact surface = 4 x 7.15 = 28.6 square inch.

Contact resistance = 0.03 x 2 / 28.6 = 0.0021 ohms.

Assuming 0.03 ohms per square inch of contact surface (Thompson Dy. Dgn. p 118.)

Potential difference over brush at rated H.P. = 0.0021 x 1780

= 3.75 volts.

$$\text{Reactance voltage} = \frac{3.14 \times \frac{565 \times 12}{60} \times \frac{2 \times 1.25}{0.52} \times 1 \times (20 \times 18.6 + 3 \times 18.6)}{10^8 \times 1.25 \times 0.006}$$

= 2.15 volts.

Field winding.

Counter E.M.F. of motor = 600- 3.73-3.52 = 591.75 volts.

Useful flux corresponding to above counter E.M.F.

$$= \frac{591.75 \times 10^8 \times 10}{580 \times \frac{45}{60} \times 10} = 13{,}800{,}000 \text{ lines.}$$

$$\text{Flux density} = \frac{13{,}800{,}000}{341}$$

= 40,500 lines per square inch.

Total flux.

Armature ----6,900,000 lines.

Air gap -----13,800,000 lines.

Teeth -------13,800,000 lines.

Pole core ---18,000,000 lines. (leakage coefficient = 1.3)

Yoke ---------9,000,000 lines.

Sectional area Armature core area = 18.6 x5 = 92 square inch.

Number of teeth under one pole = 145 x 0.7 / 10 = 10.15.

Allow for fringing, take 11.

Mean area of teeth under pole shoe = 18.6 x 0.5875 x 12 = 120 square inch.

Air gap area = 13.3 x 24 = 320 square inch.

Field core area = 24 x 11.3 = 271 square inch.

Yoke area = 112 square inch.

Flux densities:

Armature: 6,900,000/92 = 75,000 lines per square inch.

Teeth: 13,800,000/ 120 = 115,000 lines per square inch.

Air gap: 13,800,000/320 = 42,000 lines per square inch.

Core: 18,000,000 / 271 =66,500 lines per square inch.

Yoke: 9,000,000 /112 = 80,500 lines per square inch.

Mean length of one half of magnetic circuit:

Armature: $\frac{(45.28 + 5) \times 3.14}{10 \times 2} + \frac{13.3}{4} + 3.4 = 10"$.

Teeth: 2.36".

Air gap : 0.888".

Core and shoe = 4 - 0.75 =12.17".

Ampere turns per inch of magnetic path: (S.P.Thompson p.7 and 32.

Armature : 4.

Teeth : 265.

Air gap : 13000.

Core: 15.

Yoke : 20.

Apparent flux density of teeth = 115,000 lines per square inch.

True flux density of teeth = 120,000 lines per square inch.

Ampere turns per pole:

Armature : 10 x 4 = 40 .

Teeth : 2.36 x 265 = 625.

Air gap : 0.32 x 13,000 = 4,150.

Core: 4.75 x 15 = 71.

Yoke : 12.17 x 20 = 244.

Total ampere turns: 5130.

Segment lead off brushes = 29 x 0.125 = 3.62 segments.

Ampere turns per pole $= \frac{178 \times 580}{2 \times 10} = 8550.$

Demagnetizing turns per pole = 8550x 0.125 = 1070.

Distorting ampere turns = 8550 - 1070 = 7480.

Ampere turns to overcome field distortion = 2000.

Total ampere turns per pole = 5130 + 2000 + 1070 = 8200.

Current in series field = 1780 amperes.

Current density in the series turns = 700 ampere per square inbh.

Number of turns of field = 8200/1780 = 4.5 turns.

Cross section of conductor = 1780/700 = 2.54 square inch.

Width of conductor = 2.25".

Thickness of conductor = 1.125".

Width of coil = 5 x 1.225 + 5x 0.0625 + 2 x 0.05 = 6".

Thickness of coil = 2.25 + 2x 0.05 = 2.35".

Length per pole $= \frac{4.5 \times (2 \times 24 + 2 \times 11.3 + 2 \times 3.14 \times 1.125)}{12}$

= 28.8feet.

Total length = 288 feet.

Series resistance at 60° C $= \frac{9.5 \times 288}{2{,}540{,}000} = 0.00107$ ohm.

Potential difference = 0.00107 x 1780 = 1.9 volts.

Calculation of inter-pole or commutating pole.

Length of pole face parallel to the shaft = 24".

Mean length of pole arc = 5.5".

Width of pole arc = 5".

Area of cross section = 120 square inch.

Depth of pole shoe at center of arc = 1/2".

Radial length of core = 4".

Number of pole = 10.

Calculated reactance voltage = 2.15 volts.

Peripheral speed = 705 feet per minute = 11.75 feet per second

= 30 centimeter per second.

Turn per segment = 1.

Length of conductor cutting commutating field = 2 x 24 x 1 = 48".

= 122 centimeters.

Average pole face density $= \dfrac{2.15 \times 10^8}{30 \times 122} = 59{,}000$ lines.

Segments covered by brush = 3.

Number of simultaneous commutated conductors = 6.

Conductors per slot = 4.

Tooth pitch at periphery = 1.248".

Slots per pole =4.

Number of teeth spanned by pole = 4.

Cross section of pole face = 132 square inch.

Total flux = 59,000 x 132 x 1 = 7.6 mega lines.

Length of air gap = 0.188".

Ampere turns for air gap = 2,500.

Cross section of one tooth at root = 0.54 x 24 = 13 square inch.

Total cross section = 13 x 4 = 52 square inch.

Apparent tooth density = 7,600,000 / 52 x 2 = 73,000 lines.

Total ampere turns = 1200.

Core.

Total flux = 7.6 x 1.2 = 9.1 megalines.(leakage coefficient = 1.2)

Total cross section = 24 x 5 = 120 square inch.

Flux density = 9,100,000 / 120 = 76,000 lines per square inch.

Magnetic length = 4 1/2".

Total ampere turn = 1000.

Summary of ampere turns.

Air gap : 2,500

Teeth: 1200

Pole core: 1,000

Total: 4,700.

Current in inter-pole = 1780. ampere.

Number of turns = 4,700/ 1780 = 2.5.

Width of conductor = 2.25".

Thickness of conductor = 1.125".

Length per pole = 14.5 feet.

Total length = 145 feet.

Resistance at 60 C $= \dfrac{9.5 \times 145}{2,540,000} = 0.00083$ ohm.

Potential difference = 0.00083 x 1780 = 1.48 volt.

Loss = $(1780)^2 \times 0.00083 = 2,800$ watts.

Losses and heating.

Armature:

Copper loss = $(1780)^2 \times 0.00198 = 6400$ watts.

Volume of iron including teeth $= 24 \times \left\{ \frac{3.14}{4} \times (60^2 - 45.28^2) - 145 \times 2.36 \times 0.66 \right\}$

$= 25,000$ cubic inch.

Weight of core $= \dfrac{25,000 \times 480}{1728} = 6940$ pounds = 3150 kilograms.

Assuming the flux density of 11,000 lines per square centimeter, the core loss is 2.9 watts per Kilogram.

Total core loss = 3,150 x 2.9 = 9,150 watts.

Total armature loss = 6,400 + 9,150 =15,550 watts.

Gross length of armature = 24 + 0.7 x 58 = 60.4".

Cylindrical surface of armature = 60.4 x 188 = 11,350 square inch.

Watts radiated per square inch = 15,550/11,350 = 1.37 watts.

Estimated temperature rise = 1.37/0.05 = 27.4 C.

Hysteresis loss = 0.0128 x 3.75 x 25,000 = 1200 watts.

Eddy current loss in armature core without teeth

$$= 3.75^2 \times 25{,}000 \times 0.000060 = 210 \text{ watts.}$$

Total loss = 1410 watts.

Commutator :

Total area of all brushes = 7.15 x 10 = 71.5 square inch.

Electrical loss = 3.73 x 1780 = 6,650 watts.

Brush pressure = 2 pounds per square inch.

Total brush pressure = 2 x 71.5 = 143 pounds.

Coefficient of friction = 0.3.

Friction loss = 143 x 0.3 x 565 x 746 / 33,000 = 550 watts.

Total commutating loss = 7,200 watts.

Watts radiated per square inch = 7,200 / 1050 = 6.85 watts

EStimated temperature rise = 4.65 x 6.85 (1 + 0.00015 x 550)

$$= 33^\circ \text{ C.}$$

Field coil:

Copper loss at rated H.P. = $1780^2 \times 0.00107$ = 3390 watts.

Radiating surface of coil per pole

$$= 2 \times \{(24 \times 2.25) + (11.3 \times 2.25)\} + 3.14 \times 2.25^2$$

$$+ 6\{2\,(24 - 11.6) + 2 \times 3.14 \times 2.25\}$$

= 858 square inch.

Total radiating surface = 8,580 square inch.

Watts radiated per square inch = 3,390 /8,580 = 0.395 watts.

Estimated temperature rise = 0.395 x 75 = 29.2 C (assuming 75 C temperature rise per one watt).

Efficiency:

Losses:

Armature loss: 15,550 watts.

Commutator loss: 7,200 watts.

Field loss : 3,390 watts.

Inter-pole loss: 2,800 watts.

Friction loss: 4,000 watts.

Total losses: 32,940 watts

Out-put: 960,000watts.

In-put: 992,940 watts.

$$\text{Efficiency} = \frac{960{,}000 \times 100}{992{,}940} = 96.5\ \%.$$

(6) B. Design of principal mechanical parts.

Side rod:

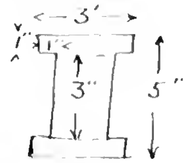
Radius of driver = 37.5".

Force at the rim of the driver = 10,000 pounds.

Radius of crank circle = 12".

Moment about the center of the driver = 10,000x 37.5 = 375,000 inch pound.

Force acting on the side rod $= \dfrac{375,000}{12} = 31,000$ pounds.



Length of side rod = 48".

Area of side rod = 9 square inch.

K = radius of gyration = 1.91.

Applying Rankine's formula for round end column

$$\text{Breaking load} = \frac{9 \times 50,000}{1 + \dfrac{4}{36,000} \times \left(\dfrac{2 \times 48}{1.91}\right)^2} = \frac{450,000}{1.276} = 350,000 \text{ pounds per square inch}$$

(See Church's M. of E. p. 369)

Factor of safety $= \dfrac{450,000}{31,000} = 11.$

As to the buckling, apply the same formula for square end,

$$\text{Breaking load} = \frac{9 \times 50,000}{1 + \dfrac{4}{36,000}\left(\dfrac{48}{1.91}\right)^2} = \frac{9 \times 50,000}{1.07} = 420,000 \text{ pounds per square inch.}$$

Factor of safety $= \dfrac{420,000}{31,000} = 13.5.$

Connecting rod.

Total force acting on the rods $= \dfrac{2,250,000}{12} = 188,000$ pounds.

Force acting on one rod = 188,000 / 2 = 94,000 pounds.

Area of connecting rod = 45 x 8.5 - 2x (1 x 6.5) = 38.5 - 13

= 25.5 square inch.

K = radius of gyration = 3.18.

Length of rod = 60".

$$\text{Breaking load} = \frac{25.5 \times 50{,}000}{1 - \frac{4}{36{,}000} \times \left(\frac{2 \times 60}{3.18}\right)^2} = \frac{1{,}275{,}000}{1.16} = 1{,}100{,}000 \text{ pounds per square inch.}$$

Crank pin:

Consider this as a cantilever.

Force acting = 31,000 pounds.

Distance between point of application and support = 12".

Material: steel (f = 60,000 pounds per square inch.)

Average area = 28.4 square inch.

Average diameter = 6".

Z= section modulus = 3.14 x 216 / 32 = 212

Strength of pin = 31,000 x 12 / 2.12 = 175,000 pounds per square inch

Calculation of jack-shaft:

Total twisting moment = 60,000 x 37.5 = 2,250,000 inch pounds.

Number of jack-shaft = 2.

Twisting moment for shaft = 1,125,000 inch pounds.

Z= section modulus = $1/2 \times (3.14 \times r^3)$,

Factor of safety = 5.

Material: steel.

$$\text{Radius} = \sqrt[3]{\frac{1{,}125{,}000 \times 2 \times 5}{3.14 \times 50{,}000}} = 4.15''.$$

Diameter = 8.3".

Bearing:

Diameter of bearing for driver = 8".

Length of bearing for driver = 15".

Projecting area = 120 square inch.

Weight on driver = 50,000 pounds.

Intensity of pressure = 50,000 / 120 x 2 = 208 pounds per square inch.

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